PAPER '1'1'1'1 .E: Mars Balloon Trajectory Model for Mars Geoscience Aerobot Development

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ABSTRACT

The Mars Geoscience Aerobot (MGA) is a proposed Mars aerobot (robotic aerovehicle) mission featuring advanced capabilities for surface imaging and atmospheric science. Development of' the MGA mission has been catalyzed by science objectives that include surface geology and atmospheric measurements. Of primary geologic interest is the nature and structure of water-lain deposits in the northern lowlands. in terms of atmospheric science, measurements of temperature, pressure, winds, IR spectra of dust, and atmospheric constituents are planned. The MGA consists of's superpressure balloon that is reflective on top and white on the bottom to avoid condensation of CO_2 frost during the night. The MGA also features a "smart" gondola with autonomous navigation capabilities that enable the acquisition of s[atc-driven, sequenced, high-resolution images based on the ability to determine position, attitude, and velocity using celestial references, inertial sensors, and image data,

Flight trajectory prediction is an integral part of MGA mission development, because the expected flight profiles (a) determine which parts of Mars can be reasonably explored by balloon, (b) drive the balloon design, and (c) are used for science sequencing and navigational cross-checks once in flight. Development of the Mars Balloon Trajectory Model (MBTM) has been an essential element of the planning and design of the MGA mission. The MBTM was developed as part of the MGA feasibility study recently conducted by the Planetary Aerobot Program of the Jet Propulsion Laboratory in conjunction with NASA- Wallops Island, Lockheed-Martin Aerospace, CNES (France), and the Space Dynamics laboratory. This paper presents details of and results from the MBTM, an integrated thermal, vertical, and trajectory model for balloon flight at Mars.

The MBTM consists of a set of differential equations which describe the motion and the thermal performance of the balloon system. The inputs to the MBTM are the balloon design and the initial conditions for the flight, including the initial location, time, and thermal state. The mode] predicts thermodynamic parameters (temperature of the balloon gas and balloon film) and the balloon trajectory.

The MBTM uses the Mars General Circulation Model ((i('M) developed at NASA Ames to determine the local atmospheric conditions at any instant in time. The GCM simulates the dynamics of the Martian atmosphere on a global scale, much like weather models for the Earth. Atmospheric parameters available from the GCM include winds, solar radiation (direct, upward diffuse, and downward diffuse), infrared radiation (upward and downward), temperature, pressure, and topography." The GCM provides 16 data points per Martian day on a grid of 7 vertical divisions, 25 latitude divisions, and 40 longitude divisions. Four-dimensional interpolation provides appropriate data between model gridpoints.

A promising design for the MGA involves a 27-m diameter, spherical, superpressure balloon. a sophisticated science gondola weighing 15 kg, and up to 3 kg of deployable scientific ballast packages. The balloon is designed to float more than 6.5 km above the planetary datum, and the MBTM shows that long-duration, 90-day missions are possible using advanced composite materials for the balloon envelope. Simulated trajectories show that several West-to-East transects are possible, covering hundreds of thousands of kilometers and more than 30 degrees latitude. Horizontal speeds range from a maximum of 80 m/s to a minimum of about 10 m/s or less with a nominal eastward velocity of nearly 40 rids. These velocities lead to circling the planet about once every 5 days at 30° latitude. Difficulties are observed when crossing the

equatorial mountain ranges, but ballast drops are shown to be an effective means of extending flight time by providing altitude change.